Development and Use of PROPHET Life Cycle Cost Model

by

Richard Barclay, Robert Craig, and William Hugo

BACKGROUND

All of us are living during the development, maturation, and aging of certain technological and social systems, their influences on each other, and their synthesis. Many of us do not recognize the significance of the synthesized products until after the combining event has passed. This paper describes the result of the three most significant trends in cost estimating of the past twenty-five years. These trends include the low cost availability of linked spreadsheets, the advent of more powerful processors in personal computers, and the dissemination by the Department of Defense of comprehensive guidance on a disciplined approach to cost estimating and standardized estimate report contents. These three trends since 1991 have opened a new era in cost estimating for acquisition and support of major defense systems.

Command Need

In early 1991 the three fundamental trends cited in the opening paragraph led to the development of the PROPHET Life Cycle Cost Model (LCCM). Other influences consisted of a developing awareness in the Naval Undersea Warfare Center Division Newport (NUWCDIVNPT) of the need to integrate cost estimating in the system design process, and the assignment of new responsibilities to NUWCDIVNPT. The synthesis of these forces is illustrated in Figure 1.

For more than a decade, NUWCDIVNPT (and earlier, NUSC) has had an expanding capability in analyzing, predicting, and tracking reliability of system components, and using reliability differences to select among system and support alternatives. The NUWCDIVNPT engineers in the Reliability Branch could assign costs to the system components being analyzed and could readily appreciate the significant differences in predicted life cycle costs (LCC) which occurred with differences in reliability. Utilizing the Naval Sea Systems Command (NAVSEA) TIGER Program[1] installed on a Cray super computer in their analyses of system reliability, they recognized and recommended that the scope of the analyses be expanded to include costs, and that the cost estimating capability be integrated with the TIGER Program. However, integration with TIGER in the Cray meant expensive development of code, as well as the development of reliable cost estimating routines which would be expressed in the code.

[1] Developed and maintained by Dr. P. J. Hartman, NAVSEA Reliability and Maintenance Engineering

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1993	ADODCAS 1993

4. TITLE AND SUBTITLE

Development and Use of PROPHET Life Cycle Cost Model

5. FUNDING NUMBERS

6. AUTHOR(S)

Richard BARCLAY, Robert CRAIG, William Hugo

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

NAUSEA - NEWPORT
Code 442, Bldg 166 TT
NEWPORT, Rhode Island 02841

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Annual Department of Defense Cost Analysis Symposium Paper

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Statement A: Approved for Public Release; Distribution is Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

See Over

14. SUBJECT TERMS

Cost Model
EMD

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
U	U	U	UL

DEVELOPMENT AND USE OF PROPHET LIFE CYCLE COST MODEL

In mid-1991 the Naval Undersea Warfare Center Division, Newport, initiated an effort to estimate the costs of notional electronic systems. Life cycle cost and particularly Engineering and Manufacturing Development (E&MD) phase cost were considered to be of equal importance to performance in evaluating the several candidate electronic systems. Adding emphasis to the need for reliable E&MD cost estimates was the inclusion of existing and partially modified existing subsystems and cabinets in the list of candidate systems.

Since development, PROPHET has been used extensively to estimate and compare the costs for the E&MD phase for different electronic system configurations. Included in these comparisons have been the costs associated with gaps in production, modifications to cabinets and displays, new hardware subsystems, alternative schedules, and changes in integration and assembly routines. Validation of the model is continuing.

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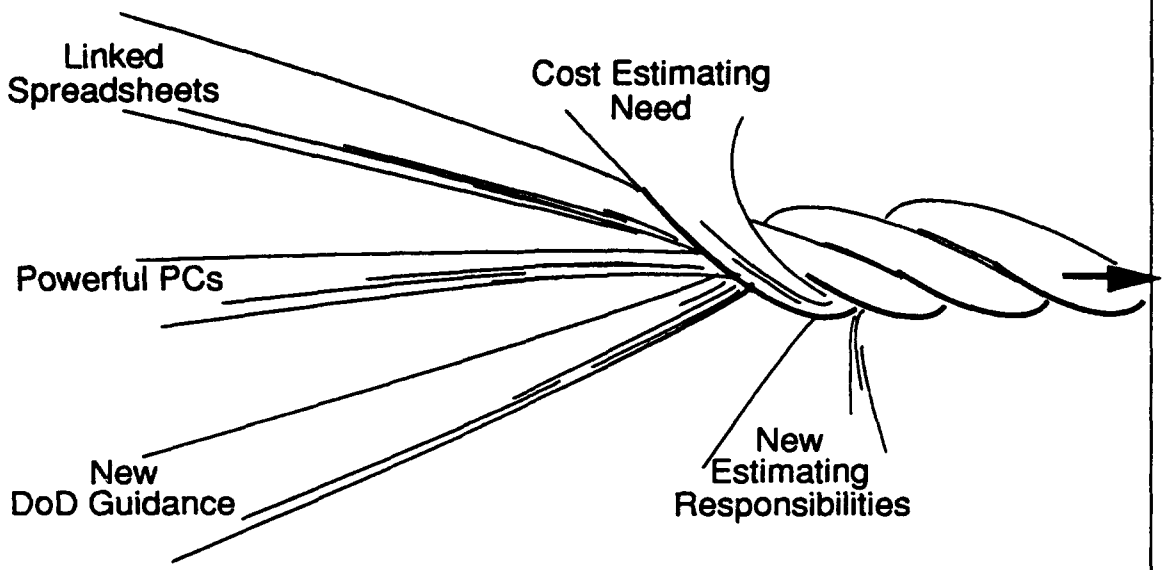
Figure 1, Synthesis of Forces



Proposed Approach Solution

NUWCDIVNPT engineers examined the requirements and resources for the development of a cost model. They considered the cost estimating personnel skills (existing or acquired through training) for laboratory staff to accomplish the cost estimates, the characteristics and availability of tools (models, databases) they would need to use, the time available to accomplish meaningful estimates of priority electronic systems, and the limited funding and time available. The examination also included study of the qualifications of known support contractors that could assist NUWCDIVNPT personnel in the development of a model.

Because of the time constraint and the limited funds available for development of a tool, coupled with the equally demanding requirements for openness, ease of operation, and tailoring, it was decided to use commercial spreadsheets rather than create a model in code or a higher order language. The results of the analysis indicated that the lowest cost, quickest, and most effective route to develop a prototype tool for estimating the LCC of electronic systems and to accomplish the necessary estimates would be to develop the prototype tool in a commercial spreadsheet. A spreadsheet was inexpensive, a fairly large number of people in and out of the Reliability Branch were skilled in their development and use, many cost elements could be included, the algorithms (cell formulas) and mathematical structure would be very visible and could be easily

programmed to respond to changed inputs, and they could easily be manipulated to generate different reports. A spreadsheet tool or model could be documented, easily operated, and easily tailored to the evolving needs of NUWC or the systems under consideration.

In mid-1991 when development commenced, it was believed that Microsoft EXCEL[2], version 3.0, and the Macintosh[3] operating environment (IIcx) offered learning curve and development speed advantages over Lotus[4] and MS/DOS[5] personal computers. This decision did speed development time, and has been non-critical subsequently as the tool has been moved to the MS/DOS environment in an Intel "486/33" and upgraded to EXCEL, version 4.0, for still greater operating speed, and without any problems. The MS/DOS version also has been easily translated back to the Macintosh operating system in EXCEL, v. 4.0.

It was determined that the structure of the model should be in compliance with the then newly issued Defense Acquisition Management Policies and Procedures, Department of Defense Instruction (DoD INST) 5000.2 and the long-established Military Standard Work Breakdown Structures for Defense Materiel Items, (MIL-STD-881A), and would be developed in two phases. Phase I of the proposed approach would involve development of the tool, and a subsequent Phase II would center on refining the tool and integrating it with the TIGER model.

During the early stages of development the tool was simply referred to as "LCCM" but as NUWCDIVNPT engineers became aware of the capabilities in the prototype tool and the growth possibilities it held, it was decided to refer to the model as "PROPHET".

ENVIRONMENT

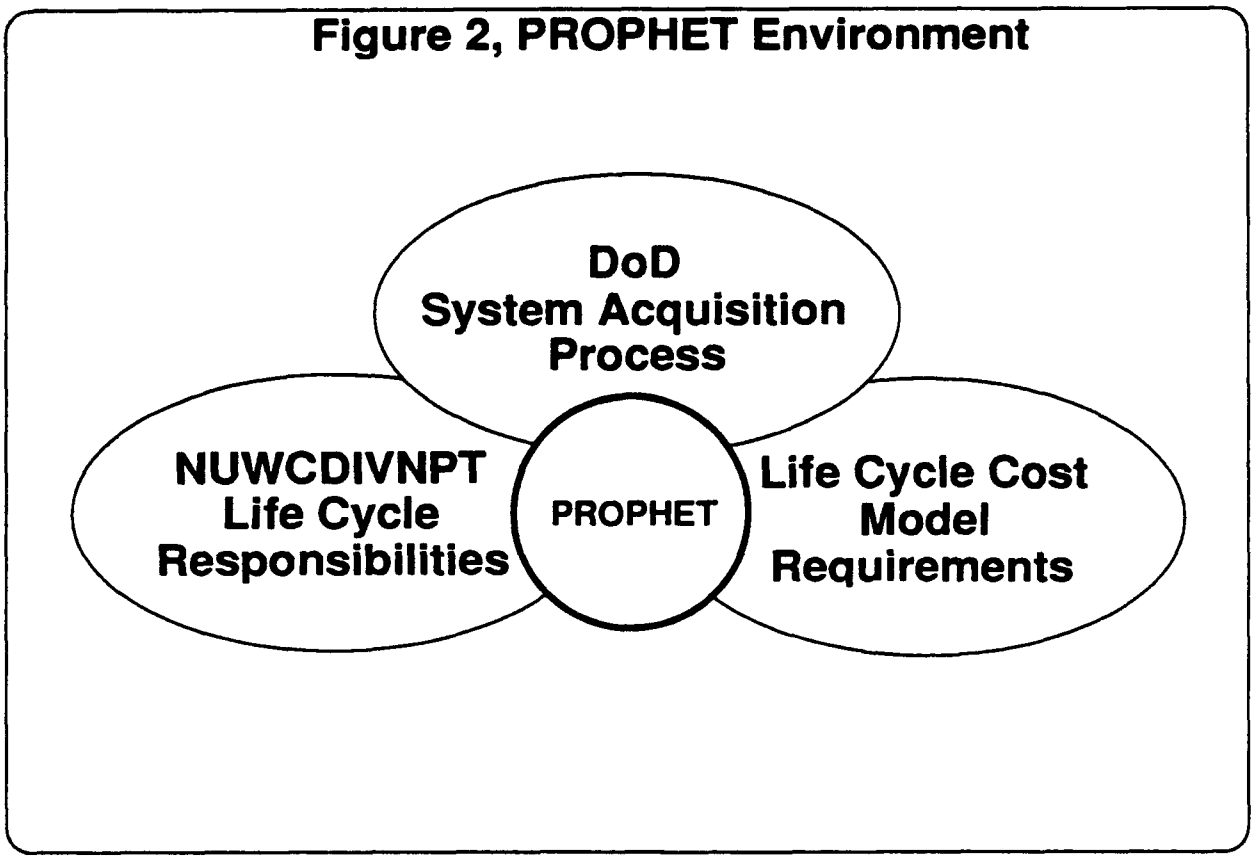
The environment in which PROPHET must operate is defined by the overlapping regions of the DoD system acquisition process, NUWCDIVNPT life cycle responsibilities and tasks, and life cycle cost model requirements imposed by NUWCDIVNPT. These regions are depicted in Figure 2.

DoD System Acquisition Process

DoD INST 5000.2 prescribes a systematic approach to acquisition of defense systems, with a series of Milestones at major decision points. Defense Acquisition Management Documentation and Reports Manual (DoD 5000.2-M) describes the reports and supporting data required in implementing an acquisition program and passing the Milestone decision points. OSD Cost Analysis Improvement Group (CAIG) Directive (DoD DIR) 5000.4 updates the charter of the Office of the Secretary of Defense Cost Analysis Improvement Group (OSD CAIG), and defines the relationships among the

[2] Excel is a trademark of Microsoft Corporation
[3] Macintosh is a trademark of Apple Corporation
[4] Lotus is a trademark of Lotus Development Corporation
[5] MS/DOS is a trademark of Microsoft Corporation

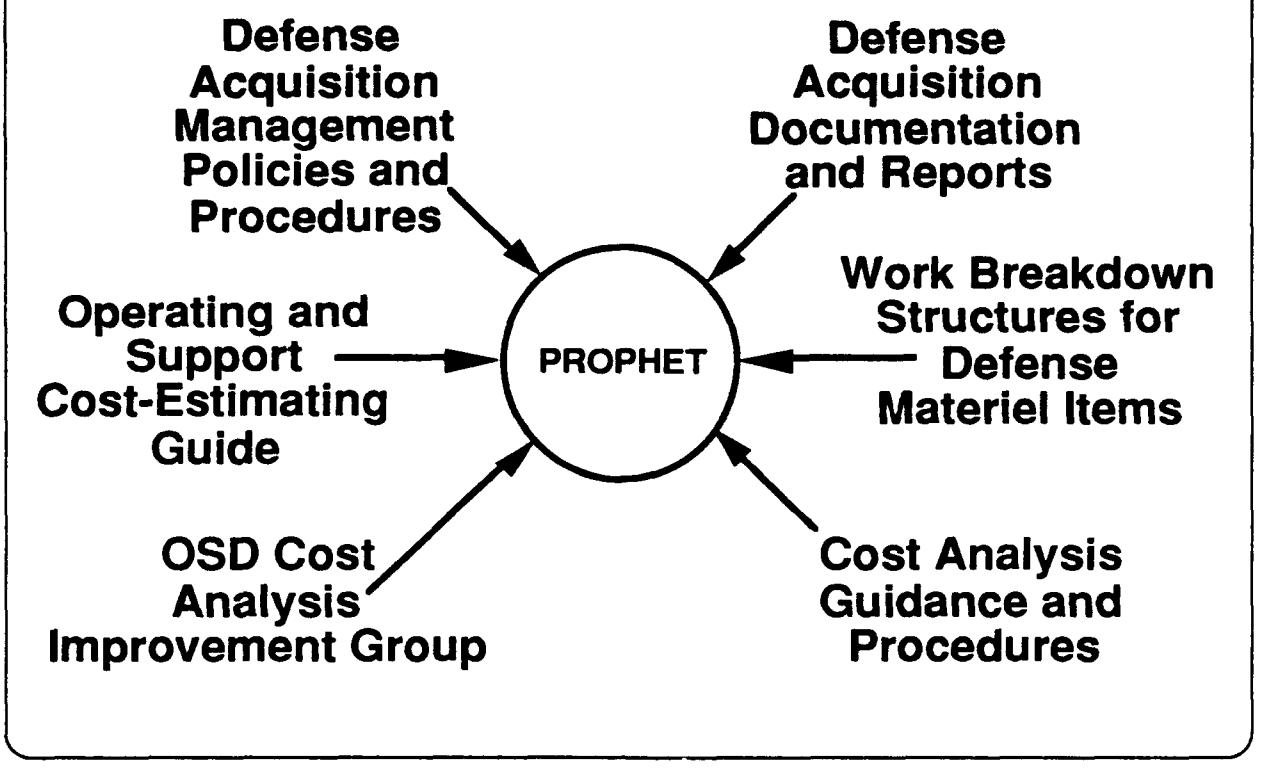
Figure 2, PROPHET Environment



CAIG cost estimates and cost estimates by the DoD Component (CCA) and Program Office (POE). Cost Analysis Guidance and Procedures Manual (DoD 5000.4-M) provides guidance on collecting and preserving the data inputs and model algorithms, and the content, scope, and presentation of cost analyses and estimates. The DoD environment influencing cost estimates is depicted in Figure 3. Together the cited instruction, directive, and manuals define the structure and content of the cost estimate reports needed to make informed and responsible decisions at the Milestones in the acquisition of a defense system. It is interesting to note that development of PROPHET commenced soon after issuance of the first two documents and well before promulgation of the detailed DoD 5000.4-M manual. Designed in accommodation to Product Improvement, careful adherence to Parts 4 and 15 of DoD Manual 5000.2-M and MIL-STD-881A, and dedication to comprehensive preservation of the estimate inputs, however, permits PROPHET to operate in compliance with the newer directives, including MIL-STD-881B, with minimum changes and effort.

The effect of the documents directly shapes the output of a cost estimate and indirectly how an estimate will be accomplished. For example, Page C-1 of Part 4 (the Integrated Program Summary) of DoD Manual 5000.2-M prescribes how the high level output of a cost estimate will look for the Development Phase (Concept Exploration, Demonstration and Validation and E&MD) and what categories of cost will be summarized in it in constant and then-year dollars for each of the requisite fiscal years. Figure 4 is an illustration of a PROPHET output for one page of an IPS. Knowing the required output format, it is theoretically possible to construct a model which will produce all the necessary

Figure 3, DoD Cost Estimating Environment



divisions of cost from a single input value. However, we don't suggest that's the way PROPHET is constructed.

Page 2 of Attachment 1 to Part 15 of DoD Manual 5000.2-M prescribes the format and content of a Program Office Estimate (POE) for the E&MD Phase with greater granularity than shown in the IPS; see Figure 5. It is interesting that the cost elements are slightly different than the categories described in MIL-STD-881B. PROPHET was designed to produce outputs in compliance with the DoD Manual 5000.2-M guidance, but due to the dimensions in PROPHET it also can generate reports in a MIL-STD-881B structure.

DoD Manual 5000.4-M, in Table 2-2, directs a slightly different breakout of cost elements for presentation to a CAIG than does DoD Manual 5000.2-M. These differences are primarily in the Support and Services area. The baseline PROPHET has not been amended as yet to provide totals for this revised list of cost elements due to funding constraints, but a special purpose modification of PROPHET has been developed and operated which does provide these details.

DoD Manual 5000.4-M also includes guidance on the schedule for submission of cost estimates and supporting documentation to the CAIG. A large portion of this manual promulgates clear definitions of what should be included in a Cost Analysis Requirements Description (CARD), and the type and amount of justification needed for Cost Estimating Relationships (CERs) contained in an estimate. The guidance in this manual is

Figure 4, Sample PROPHET Output

ANNEX B - PROGRAM LIFE-CYCLE COST ESTIMATE SUMMARY (FY 93 $M)

Run Identification: Milestone I Baseline, 4/2/93

As of Date: 6/30/93

FYs >		Footnotes	Initial FY 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	TOTAL PROGRAM
ACQUISITION QUANTITIES													
Development Qty:	Funded	1	1			3							4
	Delivered					1				3			4
DEVELOPMENT PHASE REQUIREMENTS													
RDT&E													
Concept Exploration and Definition Phase													$0.0
Demonstration and Validation Phase			$10.9	$16.8	$22.5	$13.7	$0.0	$0.0	$0.0	$0.0	$0.0		$63.9
Engineering & Manufacturing Development Phase													
Engineering & Manufacturing Development					$0.0	$8.1	$16.5	$18.2	$13.1	$11.7	$0.0		$67.6
Engineering Development Model Mfg					$0.0	$3.0	$6.6	$12.9	$14.3	$12.2	$0.0		$49.0
Test & Evaluation					$0.0	$0.7	$1.1	$1.5	$5.7	$10.1	$0.0		$19.1
Other Development Costs		2			$0.0	$0.3	$2.6	$4.0	$5.5	$7.9	$0.0		$20.3
Total RDT&E		3	$10.9	$16.8	$22.5	$25.8	$26.8	$36.6	$38.6	$41.9	$0.0		$219.9
PE XXXXX (Total RDT&E funding in Approved FYDP) (FY 93$M)			(10.9)	(16.8)	(22.5)	(25.8)	(26.8)	(36.6)	(38.6)	TBD	TBD		(178)
MILCON			$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0		$0.0
O&M		4	$0.1	$0.3	$0.3	$0.6	$0.3	$0.3	$0.3	$0.3	$0.0		$2.5
MILPERS		5	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.0	$0.0		$0.7
Total Development Phase			$11.1	$17.2	$22.9	$26.5	$27.2	$37.0	$39.0	$42.2	$0.0		$223.1

(Footnotes are on page 9)

Figure 5, Program Office Estimate Structure

Prime Mission Equipment
- Structure, Integration, Assembly
- Propulsion
- Installed Equipment
- System Software

System Test and Evaluation
System Engineering/Program Management
Peculiar Support
Training
Data
Initial Spares and Repair Parts
Operational/Site Activation
Industrial Facilities
In-House
Contingency/Risk Factor

Research, Development, Test and Evaluation (Total)
Procurement

Military Construction
Operation and Maintenance
Military Personnel

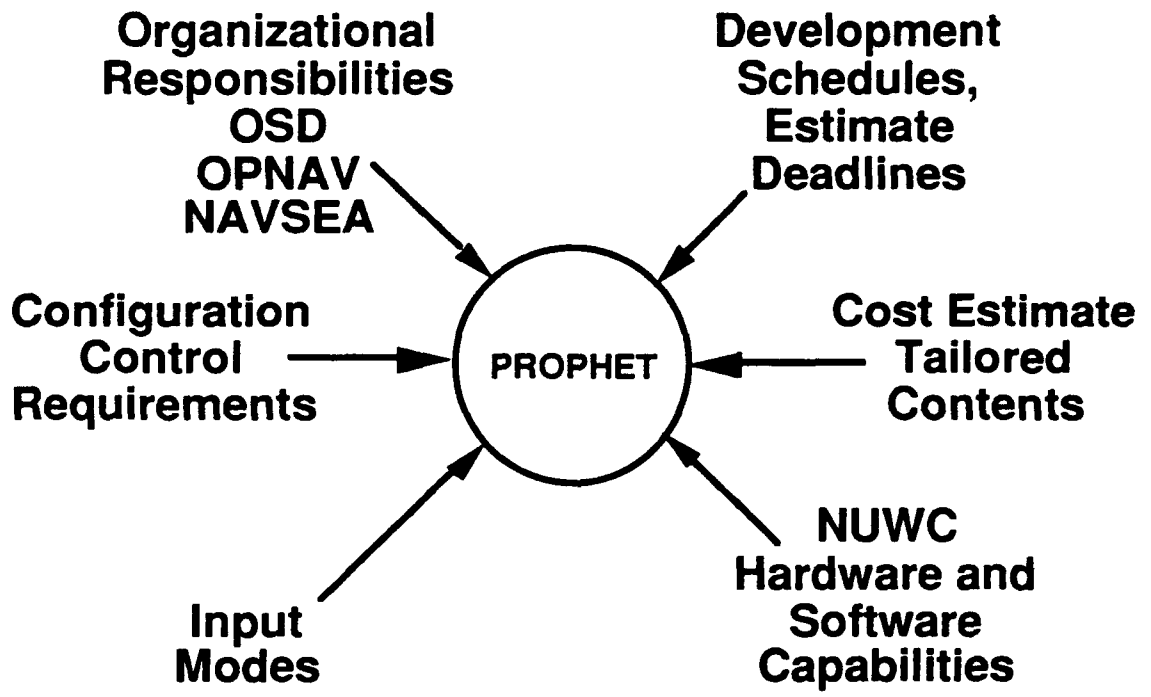
- Total Research and Development Cost Category
- Number of Units

considered a very significant advancement in the cost estimating discipline.

NUWCDIVNPT Life Cycle Responsibilities and Tasks

The second region in which PROPHET must operate is governed by the organizational responsibilities, relationships, and schedules for development of new electronic systems in the Navy in general, and NUWCDIVNPT, specifically. Primarily this dictates the scope and content of tailored cost estimate reports, absolute configuration control and archiving of inputs and outputs, and rapid, near real time operation. For example, it is helpful to some of the development engineers to input two alternative system configurations and compare the bottom-line total development costs of the two configurations, NOW. Now is often defined as less than five minutes. Figure 6 attempts to illustrate the conditions of this second region.

Figure 6, NUWCDIVNPT Estimating Environment



Quite frequently NUWCDIVNPT must respond to requests from NAVSEA or OPNAV for cost estimates of alternative systems. Engineers must prepare the input parameters for the alternatives, which can take anywhere from a few minutes to review the existing system inputs to verify absence of changes, to several weeks to define the new alternatives. Quite often, the initial estimate will trigger a new set of questions and modifications to the original inputs, followed by a sequence of further estimates.

The NUWCDIVNPT region also establishes the equipment and software

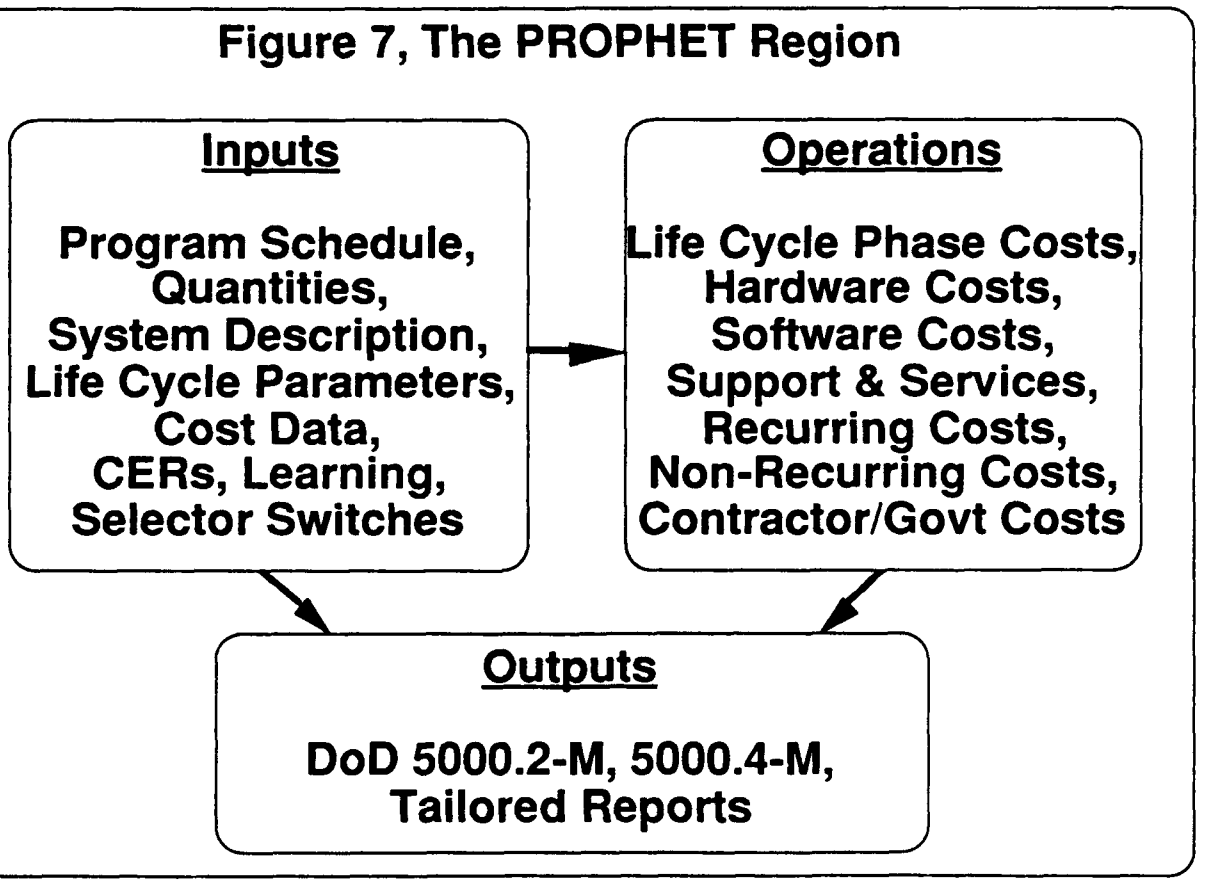
environment in which the model will operate. The prototype PROPHET is currently being maintained and operated by Reliability Branch engineers on 486/66 personal computers with MS/DOS 5.0 and Windows 3.1[6], with the Branch engineers responding to requests from development engineers. The requests for an estimate can be in the form of telephone calls, facsimile transmissions, personal visits, or memos to the Reliability Branch, or as a result of conference action items. Ultimately, it is envisioned that PROPHET will be available to any engineer in the laboratory on a network.

In summary, the DoD Acquisition Process region can be thought of as a disciplined approach to the conduct of a cost estimate, while the NUWC region is where the disciplined approach must distinguish among concepts and system architectures competing for limited funds. The third region, specific model requirements, defines how the approach can succeed in the competitive arena.

Life Cycle Cost Model Requirements

Clearly, the first two regions set the parameters for PROPHET outputs, establish the operating environment, and to a lesser degree, prescribe the performance schedule. What are the inputs to PROPHET, and what is the is the operating rule, algorithm, or structure of PROPHET? Figure 7 contains a block diagram of this region.

Figure 7, The PROPHET Region



[6] Windows is a trademark of Microsoft Corporation

PROPHET was a prototype tool which had to be completed in a short period of time. Because of the need to have visibility on the internal operations of the model for training and future integration purposes we decided to construct the model in a commercial spreadsheet. The formulas in the series of cells in the spreadsheet, even though lengthy, are more auditable than arcane code by the ultimate user engineers.

In developing the model we had a choice of limiting the inputs to a few key parameters or to including all parameters which influenced cost and which we could identify with reasonable confidence. We elected to include all those parameters which we could reasonably identify, more than 1,200 for the entire model. Our concern was that if we did not include many parameters we might not capture all the real world cost drivers in the model. Subsequently these inputs have turned out to be a good match for the contents of the CARD described in DoD Manual 5000.4-M. We consider it important that the model use the same system configuration data and level of detail as the TIGER Program to support tradeoff studies. The type of inputs for the model are listed in Table 1 and described in greater detail in a following section.

Table 1

Type of PROPHET Inputs

Schedules	System Quantities
Shore and Trainer System Quantities	Government Facilities
Crew	Government Staffing
Government Work Year Costs	Contractor Labor Rates
Contractor Indirect Rates	Learning Factors
Hardware Units and Costs	System Software Size and Languages
Support Software Size and Languages	Labor to Material Ratios
ECP and ECP Costs	Overhauls
Lowest Replaceable Unit Annual Failures	Major Modifications
Training Costs	Support and Test Equipment
Escalation Factors	Risk Factors
Scalars	Expenditure Profiles
Software Support Activity	

The requirements for the model were based not only on DoD reporting requirements, but on the ultimate objective of operating a model which could be integrated with TIGER and included capability characteristics. Because of the limited amount of time which NUWCDIVNPT personnel would have to become familiar with the model, it was important that the model be easy to operate and that inputs be readily relatable to outputs. For example, a change in the number of annual failed parts should show up in a change of output costs for depot rework costs and replenishment spares.

Specific requirements for the model included the capability to estimate phase costs for development and assembly of demonstration hardware and software, engineering development models, low rate and full rate production systems, arranged by budget categories and fiscal years, and including both contractor and Government costs.

Other specific requirements for the model included the capability to estimate life cycle costs sensitive to differences in system design, mission parameters, and logistic factors. Model requirements also included measurement of the cost impacts of alternative system configurations, component reliability, mission lengths and frequency, sparing levels, and support policies, crew skills and training, maintenance personnel skills and quantities, mean time to repair failed items, depot capabilities and work loads, and software support activity staffing.

In order for the model to accept the stated inputs and produce the required outputs in a consistent, repeatable manner, the model must be constructed in a logical arrangement and contain a mechanism or algorithm. The model arrangement and mechanism, or more properly, the mathematical structure, algorithms, and CERs in the model and the methodology embraced are described in following sections.

METHODOLOGY

The requirement to generate different detailed outputs and the need to accept many input values led to the selection of a hybrid methodology in the context of a cost engineering matrix. That is, the model is built up from low level algorithms and CERs at the cost element or work package level. These low level algorithms and CERs within the model were analogous, parametric, or cost engineering as most appropriate for the available data or the cost element. These multiple low level CERs were arranged in a cost engineering matrix based on MIL-STD-881A supplemented by the cost elements in DoD Manual 5000.2-M.

Many of the original CERs utilized in the model came from those developed by NAVSEA 06 for sonar systems and shipboard electronic systems, or from those derived by the authors from contractor data. Subsequently, some of the CERs have been replaced by ones developed by NUWCDIVNPT from recent submarine warfare systems. The need to improve the CERs is recognized and refinement, calibration, and documentation of the CERs is continuing as a priority matter. It is important to emphasize that the structure of the model permits update and replacement of the CERs.

PROPHET ARCHITECTURE

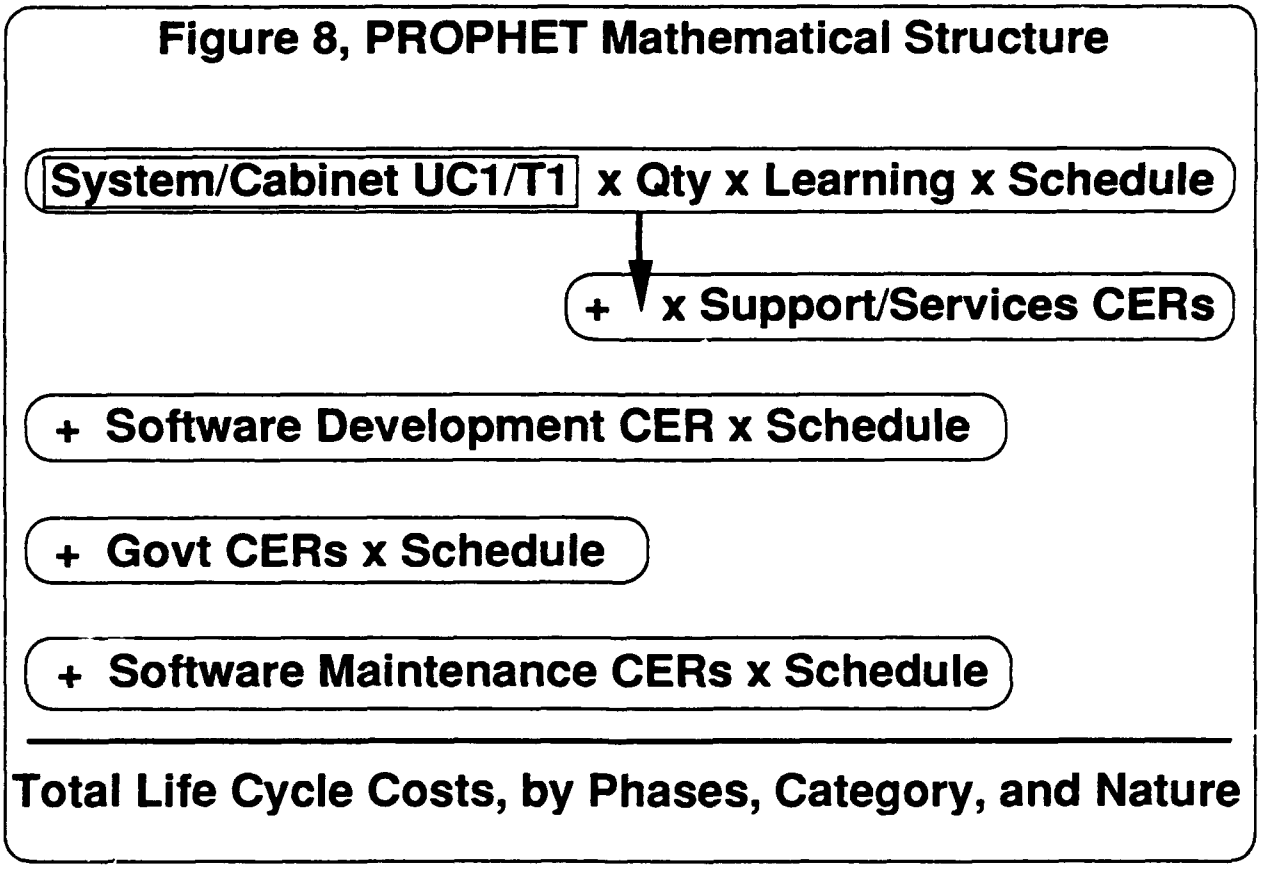
Mathematical Structure and Dimensions

The fundamental mathematical structure of PROPHET is illustrated in Figure 8. This structure is repeated, either completely or partially, throughout all the phase spreadsheets in the model. As noted below all of the input values and computed statistics are contained in one spreadsheet. CERs are used in all spreadsheets; some CERs are used in more than one spreadsheet.

We were able to create in the model all of the important dimensions needed in a cost model for a defense system. The dimensions contained in PROPHET are:

Life Cycle Phase (DoD 5000.2 defined)
Fiscal Year
Appropriation Category (RDT&E, OPN, O&MN, MPN, etc.)
Expending Organizations (Contractor or specific Government agency)
Nature of the Cost (Recurring or non-recurring)
Cost Category (Personnel, travel, minor procurement)
Contract Serial (Each one of a series of production contracts)

Figure 8, PROPHET Mathematical Structure



General Arrangement

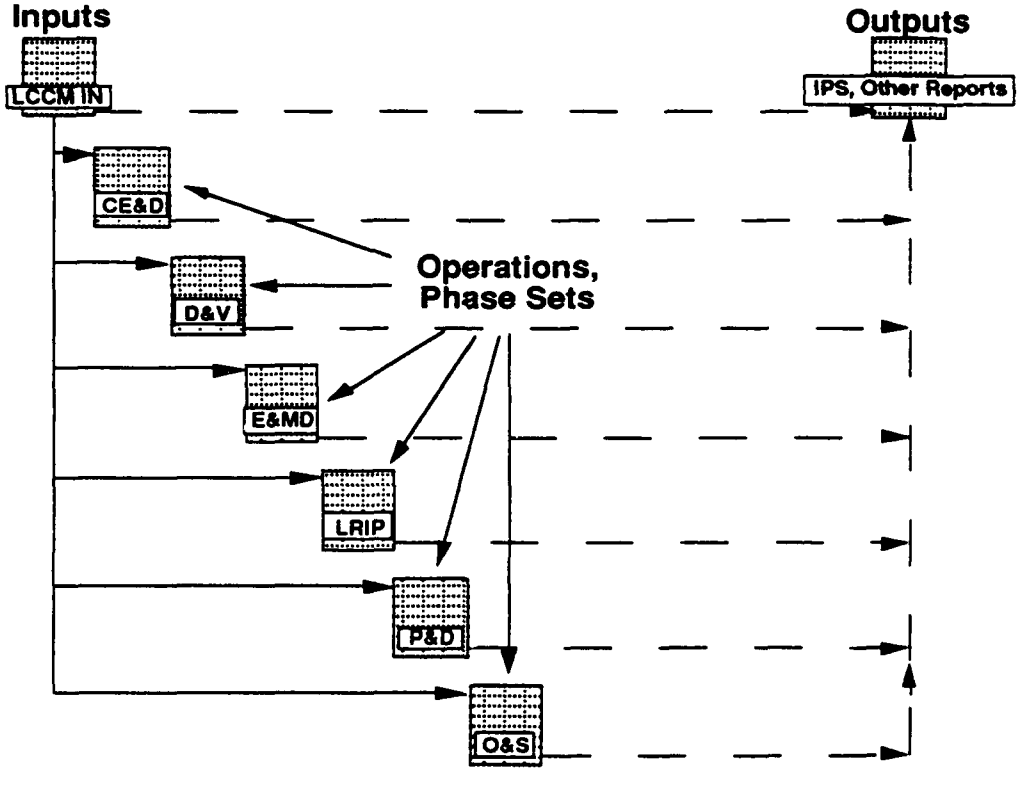
Assuming use of a commercial spreadsheet application, such as EXCEL, and the

requirement for many inputs and differently dimensioned outputs for each phase and for special purposes, it is more efficient to use linked spreadsheets than to put the entire model in one spreadsheet. Multiple, modular spreadsheets also facilitate tailoring of the model to fit different systems. This is the approach selected for PROPHET. A view of the high level architectural concept of PROPHET is provided in Figure 9.

With multiple spreadsheets it is important to limit all user input values to one spreadsheet to eliminate redundant insertion, user confusion over multiple identical inputs, and to simplify the user task of operating the model. Consequently, PROPHET has all inputs in one master spreadsheet, called LCCM IN.

Each life cycle phase has at least one spreadsheet focused on that phase. Most phases have several spreadsheets, with one estimating Prime Mission Equipment costs, another estimating System Integration and Assembly and Software costs, two other spreadsheets estimating Contractor Support and Service costs, and several more estimating the cost of each Government agency involved in the program. There are also one or more spreadsheets for collecting and summarizing costs for output reports. Currently, PROPHET contains 63 spreadsheets, but an "advanced PROPHET" will reduce that number to 17 including the Integrated Summary Report.

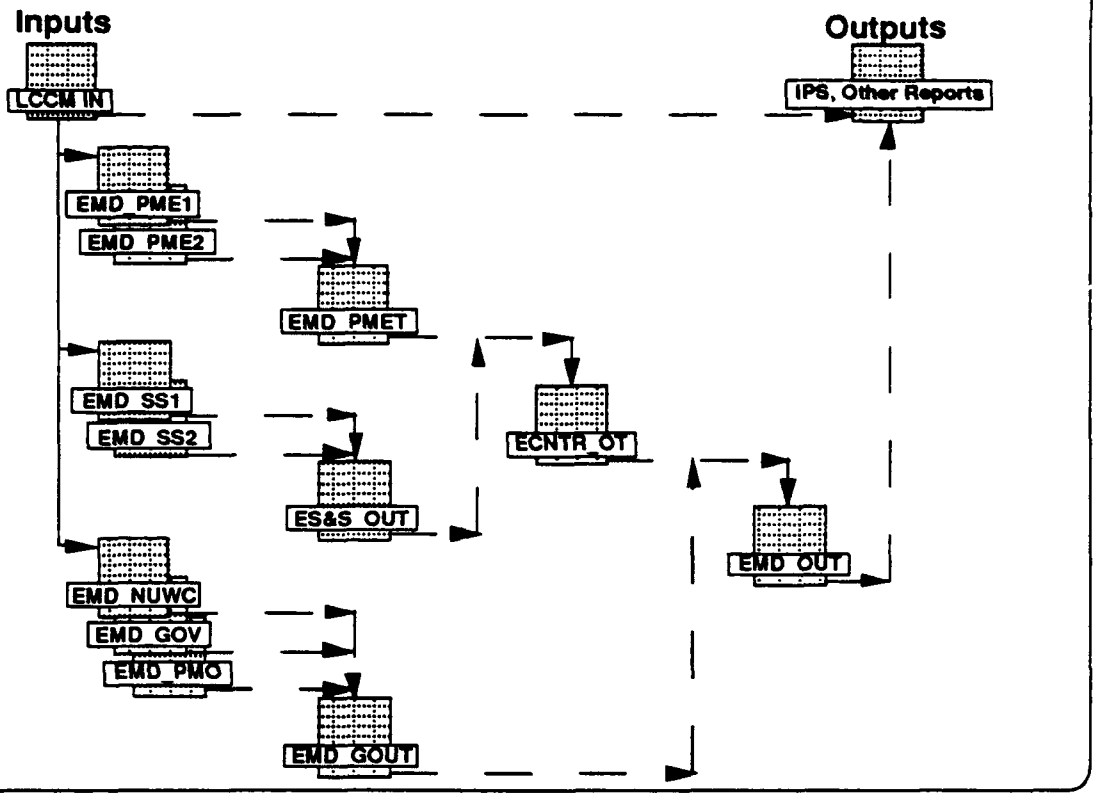
Figure 9, PROPHET Architectural Concept



E&MD Phase Structure

The E&MD Phase consists of seven spreadsheets for estimating costs and five collector spreadsheets in an arrangement depicted in Figure 10. Each spreadsheet

Figure 10, PROPHET E&MD Architecture



contains a section at the top where input values and computed data from LCCM IN is linked into cells. It is these "linking cells" which are referenced in the formulas in the body of the spreadsheets for estimating the costs of specific WBS elements. A subsequent version of PROPHET eliminates this two-step linking process and references named LCCM IN values in the body of the phase spreadsheets. The arrangements within the EMD_PME1 and EMD_PME2 (MS/DOS version nomenclature) spreadsheets are illustrated in Figures 11A and 11B. The structure and data flow from hardware through software to system integration is visible. WBS element numbers in the current model were inserted as generic identifiers only and do not represent any specific system WBS. The WBS identifiers can be changed to represent the specific WBS of the system being estimated.

Examples of the structure and flow in the Contractor Support and Services E&MD spreadsheets are shown in Figures 12A and 12B. The costs for each element are estimated separately and then collected at the bottom of the spreadsheets. The work package groups are visible in the figure outlines, and their similarity to the DoD Manual 5000.2-M cost elements can be traced.

Similarly, the structure of the Government spreadsheets is depicted in Figure 13. All of the values and computed statistics in these E&MD spreadsheets come from the links to LCCM IN.

Figure 11A, E&MD PME1 Arrangement

Linked Data from LCCM IN

Prime Mission Equipment (CFE) in base year $, by years
Contingency/Risk $ for PME, by years

Figure 11B, E&MD PME 2 Arrangement

Linked Data from LCCM IN
Software Development for new system SLOC, by years
Software Development for modified utility SLOC, by years
System Integration Requirements and Planning
System Production Design
Production Process Design
Inspection, Setup, and Removal
Integration Activities
Integration/Production Test Site
Acceptance Test
Design Maintenance
System Integration & Assembly (SI&A) Administrative Engineering
SI&A Tooling
Prime Mission Equipment (GFE)
GFI/Software for GFE
Auxiliary Hardware/Software
Maintenance Assistance Modules
Engineering Changes
Software Maintenance
Packaging, Handling, Storage & Transportation
Contingency/Risk $, by years

Figure 12A, E&MD SS1 Arrangement

Linked Data from LCCM IN

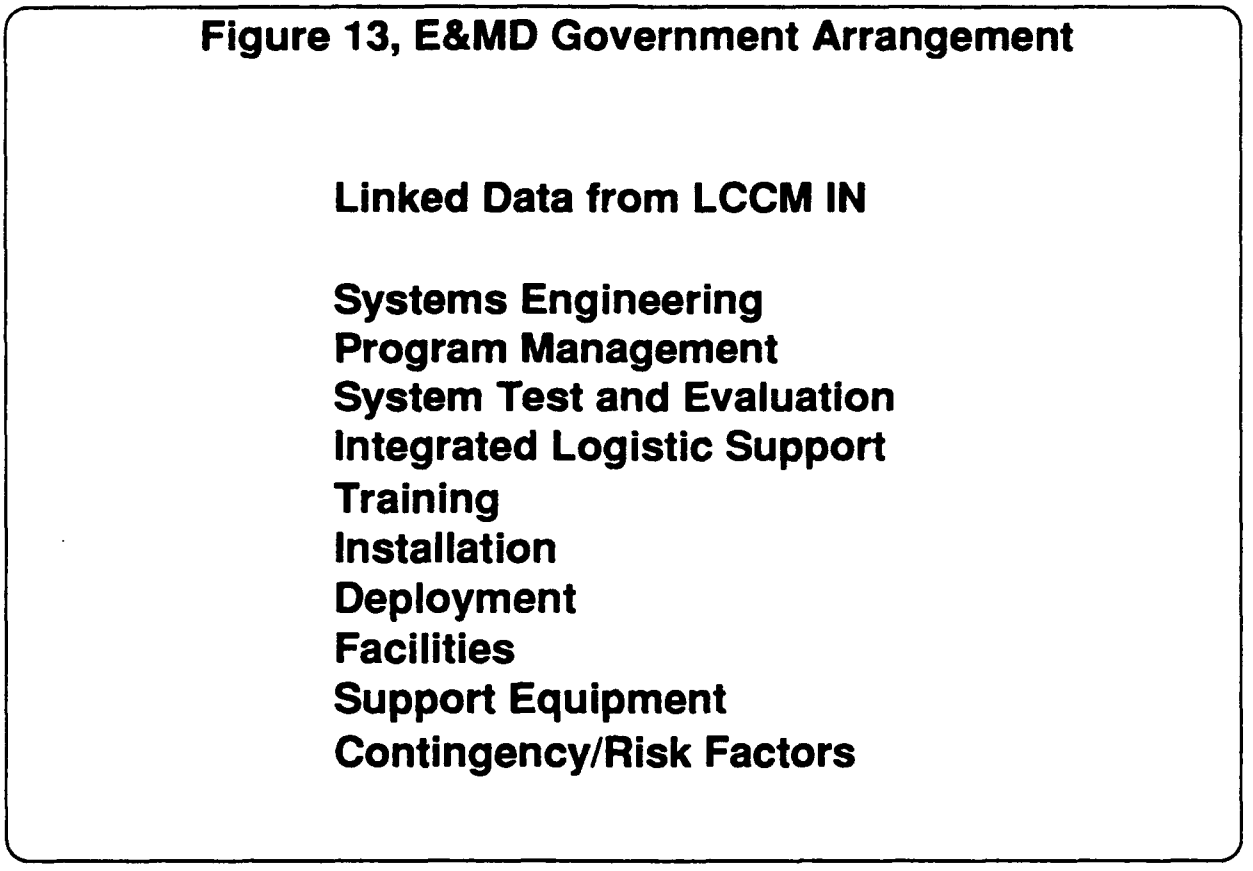
Systems Engineering
Program Management
System Test and Evaluation
Integrated Logistic Support
    Data
Training
Contingency/Risk Factors

Figure 12B, E&MD SS2 Arrangement

Linked Data from LCCM IN

Installation
Deployment
Facilities
Support Equipment
Contingency/Risk Factors

Figure 13, E&MD Government Arrangement



INPUTS

Categories

The different categories of inputs in PROPHET are listed in Table 1, shown previously. The number of input values within a category can vary from one to several dozen. One example of an input is the fiscal year in which the third production contract option is exercised. Another example is the number of Sonarman, Third Class in the crew of a submarine or ship. A third example is the percentage of fabrication labor involved in the second year of a contract. All of these input values can be changed from run to run. The sum total of all these inputs represents the value portion of the CARD for that particular run. Printing LCCM IN, the input spreadsheet and archiving it electronically is a means of preserving the input values for a cost estimate of a specific system or program alternative.

The inputs are used in CERs and estimating algorithms in the dependent phase spreadsheets to develop the cost of individual elements.

Switches

The input spreadsheet, LCCM IN, also contains several switches. These are used to control which of two or more input values, functions, or CERs are used in any specific run of PROPHET. For example, the model contains a switch to select either one

of two learning curves, Cumulative Average or Unit Cost. Another switch selects between use or non-use of concurrent engineering by the contractor. Still another switch selects use of either calendar attrition or operating hours in estimating Operating and Support costs.

Cost Estimating Relationships

The model contains two main types of CERs, those which are embedded in the model in the form of mathematical statements or cell formulas, and those which are inserted as specific values for a discrete activity. For example, in the E&MD Contractor Support and Services number 1 (EMD_SS1) spreadsheet row for estimating the cost of Value Engineering, a CER takes the:

Input value from LCCM IN for the percentage of the total system which is new development, and

Multiplies it by the total dollar value of System Engineering, and

Multiplies it again by the percentage of System Engineering which is the Value Engineering share (an embedded CER).

We obtained this CER from analysis of a contractor cost data report (CCDR), but we recognize that we have to expand our research and refinement of the CERs.

Computed Statistics

In LCCM IN, the master spreadsheet, we have established databases, particularly for the hardware inputs, and generated statistics from the values for the cabinet, component, and Lowest Replaceable Unit (LRU) quantities and costs. These computed statistics are used in the PME set of spreadsheets to develop system costs. They are also used in the Support and Services spreadsheets to estimate selected support functions such as System Engineering.

Functions

We developed special user defined functions for PROPHET to simplify formulas in calculating learning. While not an input in the sense that a casual user would insert these functions to operate the model, functions have been installed and are available for use anywhere in the model. Both average recurring cost (ARCLRN) and total recurring cost (TRCLRN) functions are operative. Further, the user can select between Cumulative Average Cost and Unit Cost curves (Wright and Thompson curves) by inserting the digits 1 or 2 in a designated cell ("switch") in LCCM IN.

FUNCTIONAL USE

Insertion of Variables

The first step in use of PROPHET is to open the Excel application, followed by opening of LCCM IN, the spreadsheet where inputs are entered. The user can scroll

through the spreadsheet to review the inputs which are in the cells, and change whichever values are needed to reflect the new system to be estimated. A sample of one page of LCCM IN concerning system quantities is shown in Figure 14. The first scroll through LCCM IN may require several hours to ascertain where categories of values are located, but frequent use speeds up the search process. In addition, all the normal EXCEL functions are available, such as FIND "a certain string of characters".

Operation of PROPHET

After all inputs have been entered in LCCM IN the user can sequentially open and close each phase spreadsheet in sequence and then the report summary spreadsheets. This sequence of opening and closing spreadsheets will permit the input values for that system/program configuration to be acquired and used by all the dependent spreadsheets and the model will generate an updated report of life cycle costs. PROPHET also contains a macro executed by a "RUN" button at the bottom of LCCM IN which will accomplish the process automatically and faster than a human operator can run the model.

If a new report format is desired, the user can quickly create a new spreadsheet in the appropriate format, and then invoke links in the desired cell format to the estimated values in the phase or collector spreadsheets. Future operations of the model would then automatically update the values in the new report if it is opened, either with the source spreadsheets opened, or by a positive response to the question, "Update external references?"

We have operated this prototype tool extensively over the past two years and it has performed much better than we expected. We have observed great flexibility and adaptability to conditions beyond what we originally set in the model. We have learned a lot from it. That isn't to say we haven't noticed any refinements that should be made, and that we intend to make in the next generation.

CONCLUSION

The use of commercial spreadsheet applications and more powerful personal computers provides cost estimators and analysts with a more powerful tool than any they had before. The tool is flexible and can be quickly modified to meet changing input or report conditions. Literally, thousands of input values can be inserted in a suitably designed new model.

Adherence to the newly published DoD Manual 5000.4-M guidance coupled with the new spreadsheets and computers shapes a more disciplined and effective approach to cost estimating for defense systems.

The next biggest hurdle to overcome is the compilation of reliable databases and the derivation of dependable and accurate CERs. We're starting on that task now.

Figure 14, Sample LCCM IN Page

Common/Standard Values

System Quantities

Milestone 0	1992
Milestone I	1993
Milestone II	1994
Milestone III	2000
Milestone IV	2010

Engineering and Manufacturing Development

Phase Total 0

Forward Fit	0
Back Fit	
FY	1994

(Constraint 1994-1997)

Will "hard tooling" be first used in EMD?	No
Will "hard tooling" be first used in LRIP?	No
Will "hard tooling" be first used in FRP?	Yes

Low Rate Intitial Production

Phase Total 3

	1st Year	2nd Year	3rd Year
Forward Fit	3	0	0
Back Fit			
FY	1998	1999	2000
	(Constraint 1995-1999)	(Constraint 1996-2000)	(Constraint 1997-2001)

Full Rate Production

Phase Total 37

	1st Year	2nd Year	3rd Year	4th Year	5th Year
Forward Fit	3	3	4	4	5
Back Fit					
FY	1999	2000	2001	2002	2003
	(Constraint 1999-2003)	(Constraint 2000-2004)			

No. of Production Contracts 9

System Total 40

	6th Year	7th Year	8th Year	9th Year	10th Year
Forward Fit	5	5	5	3	0
Back Fit					
FY	2004	2005	2006	2007	2008

System Trainers & Shore Systems

Total 2

Trainers Only 1

	Trainers			Shore Systems	
	1st Year	2nd Year	3rd Year	1st Year	2nd Year
Op Tmrs	1	0	0	1	0
Maint Tmrs					
FY	2000	2001	2002	2002	2003
	(Constraint 1995-1999)				